Economic Policy Uncertainty and the Yield Curve

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Motivation

General Research Question:
**How does economic policy uncertainty affect the yield curve?**

Some examples:

- **Government/fiscal policy uncertainty:**
  1. Gulf War (invasion of Iraq)
  2. Debt Ceiling crisis in congress and temporary government shutdown

- **Monetary policy uncertainty:**
  1. Quantitative Easing (QE)
  2. Tapering

Interpretation: Economic policy uncertainty relates to

- the uncertain impact of a given policy
- **AND the uncertainty about which policy the government/central bank is going to implement.**

Proxy for policy uncertainty: Index developed by Baker et al. (2012)
Panel A: Term Structure and Policy Uncertainty

Panel B: Volatility and Policy Uncertainty

- Average correlation between GPU (MPU) and Yields: -0.43, (-0.01)
  Increase in government policy uncertainty leads to a decline in nominal bond yields (flight-to-quality)

- Average correlation between GPU (MPU) and realized volatility: 0.54, (0.18)
  → Increase in policy uncertainty leads to an increase in nominal bond yield volatility
Important observation:

- Unconditional realized bond volatility is hump shaped in time to maturity $\tau$.

Is policy uncertainty key determinant of the shape of bond yield volatility?
Literature Review

1. Affine Term Structure Modeling (in general equilibrium):

2. (Economic) Policy Uncertainty:

3. Bond risk premium:
   - Fama and Bliss (1987), Campbell and Shiller (1991), Cochrane and Piazzesi (2005), Ludvigson and Ng (2009)
Contributions and Results

What we do in this paper

- Solving a consumption/investment problem using perturbation methods where there are both, fiscal and monetary policy shocks, and derive the equilibrium yield curve in closed-form
- Capture the flight-to-quality behavior (negative relationship between yields and policy uncertainty), and
- the empirical (hump-) shape of the term structure of bond volatility

Empirical analysis

- Suggests that economic policy uncertainty has a significant effect on both the yield curve and its corresponding term structure of bond volatility
Model Economy

GPU

Central Bank

Nominal Side
Money Supply

Endogenous
Money Supply
(Taylor Rule)

Exogenous
Money Supply
(Decoupled)

Real Side
Output
(Productivity)

Money
Neutrality

MPU
Assumption (The Real Side of the Economy)

\[
\begin{align*}
GDP: & \quad \frac{dY_t}{Y_t} = (\mu_y + q_A A_t) \, dt + \sigma_y \sqrt{g_t} \, dW_t^Y, \quad Y_0 \in \mathbb{R}_+, \\
Prod: & \quad dA_t = (\kappa_A (\theta_A - A_t) + \lambda g_t) \, dt + \sigma_A \sqrt{g_t} \, dW_t^A, \quad A_0 \in \mathbb{R}, \\
GPU: & \quad dg_t = \kappa_g (\theta_g - g_t) \, dt + \sigma_g \sqrt{g_t} \, dW_t^g, \quad g_0 \in (0, \infty)
\end{align*}
\]

Implications:

- GDP growth is time-varying in productivity \( A_t \) whenever \( q_A \neq 0 \).
- Refer to \( g_t \) as fiscal/government policy uncertainty (GPU).
- Government policy uncertainty negatively affects long run growth whenever \( \lambda < 0 \).
- Government policy uncertainty \( g_t \) is fundamental driver of real risk and long rung growth.
Assumption (Taylor Rule for Money Supply)

\[
\frac{dM_t^S}{M_t^S} = \mu_M dt + \eta_1 \left( \frac{dK_t^*}{K_t^*} - \bar{k} dt \right) + \eta_2 \left( \frac{dp_t^*}{p_t^*} - \bar{\pi} dt \right) + \sigma_M \sqrt{m_t} dW_t^M
\]

\[
dm_t = \kappa_m (\theta_m - m_t) dt + \sigma_m \sqrt{m_t} dW_t^m,
\]

where \( \mu_M \in \mathbb{R} \) and \( \sigma_M > 0 \) are the unconditional constant mean and volatility of money growth.

- Parameters \( \eta_1 \in \mathbb{R} \) and \( \eta_2 \in \mathbb{R} \) determine the weighting of the central bank of the two target growth rates of real output and inflation.
- Active monetary policy if \( \eta_1 \neq 0 \) and \( \eta_2 \neq 0 \).
- In equilibrium, economic policy uncertainty affects both capital growth and inflation implicitly.
- Refer to \( m_t \) as monetary policy uncertainty. MPU renders central banks money supply volatility state dependent.
Assumption (Preferences of Representative Agent)

\[ U(X_t) = E_t \int_t^{\infty} e^{-\beta(u-t)} U(X_u) du, \beta > 0 \]

where \( U(X_t) = \frac{1}{\gamma} (X_t^\gamma - 1), X_t = C_t(M_t^d)\xi, 0 \leq \xi \leq 1 \)

- \( \gamma \) denotes one minus the coefficient of risk aversion
- When \( \gamma = 0 \), separable log-preferences: \( U(X_t) = \log(X_t) \)

Assumption (Capital budget constraint)

The real after-tax return on capital that can either be allocated to consumption \( C_t \) or cash balances \( M_t^d \) and/or reinvested:

\[ C_t dt + M_t^d dt = K_t \frac{dY_t}{Y_t} - \delta K_t dt - dK_t \]

where \( K_t \frac{dY_t}{Y_t} \) is total output, \( \delta K_t dt \) is capital depreciation with \( \delta \in [0, 1] \) and \( dK_t \) is time \( t \) period investment.
The representative agent’s equilibrium is defined as a vector of optimal consumption and money demand controls \([C^*_t, M^d*_t]\) and equilibrium price process \(p^*_t\) with value function

\[
V(t, K_t, A_t, g_t) = \mathbb{E}_t \left[ \int_t^\infty e^{-\rho(u-t)} U(C_u, M_u^d) du \right]
\]

such that the dynamic HJB programming problem is solved

\[
0 = \frac{\partial V(t, K_t, A_t, g_t)}{\partial t} + \max\{U(C_t, M^d_t) + AV(t, K_t, A_t, g_t)\}
\]

and subject to

- representative agent’s preferences
- the intertemporal budget constraint
- the monetary policy rule
- money market-clearing \(M^S_t = p^*_t M^d*_t\)
- transversality condition
Proposition (Equilibrium Capital Stock & Money Holdings)

1. The agent's first order asymptotic optimal controls are

\[ C_t^* = \frac{\beta K_t}{1 + \xi} \left[ 1 + \gamma \left( L - g_0(X_t) \right) \right], \quad M_t^{d*} = \xi C_t^*. \]

2. The equilibrium capital accumulation \( K_t^* \) and price process \( p_t^* \) satisfy

\[
\frac{dK_t^*}{K_t^*} = \mu_{K}^* (A_t, g_t) \, dt + \sigma_Y \sqrt{g_t} \, dW_t^Y \\
\frac{dp_t^*}{p_t^*} = \left[ \frac{\mu_M - \eta_1 \bar{k} - \eta_2 \bar{\pi}}{1 - \eta_2} + \frac{\eta_1 - 1}{1 - \eta_2} \mu_{K}^* (A_t, g_t) - g_t \left( \eta_1 - 1 \right) \frac{\sigma_Y^2}{1 - \eta_2} \right] \, dt \\
+ \frac{\sigma_M \sqrt{m_t}}{1 - \eta_2} dW_t^M + \left( \eta_1 - 1 \right) \sigma_Y \sqrt{g_t} dW_t^Y.
\]

- \( \mu_{K}^* (A_t, g_t) := \mu_Y + q_A A_t - \beta - \delta + \gamma \beta \left( g_0(A_t, g_t) - L \right) \) denotes the equilibrium drift of the capital accumulation process.
- \( C_t^* \) and \( M_t^{d*} \) are both linear in \( K_t \) and \( X_t \).
1. Nominal Term Structure of Interest Rates

\[ Y(t, \tau) = -\frac{1}{\tau} (\log(B(t, \tau))) = \frac{b_0(\tau)}{\tau} + \frac{b_A(\tau)}{\tau} A_t + \frac{b_g(\tau)}{\tau} g_t + \frac{b_m(\tau)}{\tau} m_t \]

2. The nominal short rate \( R_t \) is given by

\[ R_t = C_0^R(\gamma) + C_A^R(\gamma) A_t + C_g^R(\gamma) g_t + C_m^R m_t \]

3. The nominal price of fiscal risk \( \lambda_{t,N,g} \) as well as the market price of monetary risk \( \lambda_{t,N,m} \) are

\[ \lambda_{t,N,g} = \frac{\eta_2 - \eta_1}{\eta_2 - 1} \sigma_Y \sqrt{g_t}, \quad \lambda_{t,N,m} = \frac{\sigma_M}{\eta_2 - 1} \sqrt{m_t}. \]

4. The bond risk premium \( RP(t, \tau) \) per unit of time is given by

\[ RP(t, \tau) := \frac{1}{dt} \mathbb{E}_t \left[ \frac{dB(t, \tau)}{B(t, \tau)} - R_t dt \right] \]

\[ = \lambda_{t,N,g} \left[ b_A(\tau) \rho_A^Y \sigma_A + b_g(\tau) \rho_g^Y \sigma_g \right] \sqrt{g_t} + \lambda_{t,N,m} b_m(\tau) \rho_m^M \sigma_m \sqrt{m_t} \]

where \( b_g(\tau) \) and \( b_m(\tau) \) are time to maturity \( \tau = T - t \) functions.
Max. Likelihood Estimation of Feller processes

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<tr>
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</table>

Table: Estim. period is Jan 1990 to Jun 2014 using monthly data.

- Important difference: $\hat{\kappa}_g$ half of $\hat{\kappa}_m$. The half-life of a shock in $g_t$ is $-\log(0.5)/\hat{\kappa}_g = 1.48$ months ($0.72$ months for MPU), which implies that it takes about six weeks (three weeks) for a shock to government (monetary) policy uncertainty to die out by half.
  → Government policy shocks more persistent.

- Asymptotic robust standard errors ('Sandwich estimator') of the parameters based on the outer product of the Jacobian of the log-likelihood function.
### Model Parameters

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<tr>
<th>Parameter</th>
<th>Value</th>
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### Remarks:

- Parameters in **blue** calibrated to match simultaneously, the average yield curve and bond volatility curve.
- Parameters in black are computed sample means, variances and covariances.
- Central bank decreases money supply whenever \( \left( \frac{dK_t^*}{K_t^*} - \bar{k}dt \right) > 0 \) or \( \left( \frac{dp_t^*}{p_t^*} - \bar{\pi}dt \right) > 0 \) as both $\eta_1$, $\eta_2 < 0$.
- $\lambda < 0$ and large, implies that fiscal policy uncertainty negatively affects $A_t$.
- First two centered moments of GDP and money supply growth set to their unconditional estimates.
- Simulation of economy for $N = 2'500$ time steps and number of Monte-Carlo runs is 1'000.
Key observation:

- Model is able to match hump-shape in bond volatility while simultaneously producing a good fit of the term structure.
- Total Error is 7.78%.
Remarks:

- \( \lambda < 0 \) crucial to replicate hump in bond volatility curve.
- Persistence of fiscal policy uncertainty shocks need to be high, i.e. \( \kappa_g \) low.
Remarks:

- Magnitude of fiscal policy shock $\sigma_g$ raises level of bond volatility (hump-shape).
- Time-varying component of GDP growth $q_A$ effects mainly level of bond vol but not its shape.
Remarks:

- Term structure very sensitive to changes in risk aversion. (Flight-to-quality even more pronounced)
- Parallel downward shift of bond volatility curve when risk aversion ↑
Remarks:

- Shape of yield curve changes substantially if $\eta_1$ or $\eta_2$ are reduced by 20%.
- Large level and shape effect of vol. if $\eta_1$ or $\eta_2$ are reduced by 20%.
Where does the hump-shape come from?

Remarks:

- The factor loading on fiscal policy uncertainty and its covariance with productivity $A_t$ are hump-shaped.
Where does the hump-shape come from?

Under some conditions:

- \( b_g(\tau)/\tau \) and \( \frac{b_A(\tau)}{\tau} b_g(\tau) \) is hump-shaped (necessary condition).
- Impact of fiscal policy shocks negative, \( \lambda < 0 \).
- Need both \( \kappa_A \) and \( \kappa_g \) low, mainly \( \kappa_g \) (high persistence of shocks to government policy uncertainty \( g_t \)).
- Government impact volatility \( \sigma_g \) is large.
- Stationary variance of \( g_t \) and covariance \( g_t \) and \( A_t \):
  1. \( \mathbb{V}[g_t] = \lim_{T \to \infty} \mathbb{V}_t[g_T] = \frac{\theta_g \sigma_g}{2\kappa_g} \)
  2. \( \mathbb{C}[A_t, g_t] = \lim_{T \to \infty} \mathbb{C}_t[A_T, g_T] = \frac{\theta_g \sigma_g (2\kappa_g \rho A g \sigma_A + \lambda \sigma_g)}{2\kappa_g (\kappa_A + \kappa_g)} \)

\( \rightarrow \lambda \) is unconstrained which helps to regulate impact of \( \mathbb{C}[A_t, g_t] \) on bond volatility.
- Both \( \mathbb{V}[g_t] \) and \( \mathbb{C}[A_t, g_t] \) need to be large
Testing the model predictions

- **H1**: Higher policy uncertainty decreases nominal yields.

\[
\frac{\partial Y(t, \tau)}{\partial g_t} = \frac{b_g(\tau)}{\tau} < 0, \quad \frac{\partial Y(t, \tau)}{\partial m_t} = \frac{b_m(\tau)}{\tau} < 0, \quad \forall \tau \geq 0.
\]

→ Main driver of this effect is government policy uncertainty.

\[
\left| \frac{b_g(\tau)}{\tau} \right| > \left| \frac{b_m(\tau)}{\tau} \right|
\]

- **H2**: Higher policy uncertainty increases nominal yield volatility. This effect is stronger for government policy uncertainty.

\[
\frac{b_g^2(\tau)}{\tau^2} \text{Var}[g_t] > \frac{b_m^2(\tau)}{\tau^2} \text{Var}[m_t]
\]

- **H3**: The contribution of government policy uncertainty, i.e.

\[F_g(\tau) = \frac{b_g^2(\tau)}{\tau^2} \text{Var}[g_t]\] to bond yield volatility is hump-shaped.

- **H4**: Bond risk premium is increasing in both monetary \(\lambda_t^{N,m}\) and government policy uncertainty \(\lambda_t^{N,g}\).
Yields and Policy Uncertainty

Felix Matthys

Motivation
Model Economy
Equilibrium Term Structure
Calibration of the model
Comparative statics: Yield Volatility
Empirical Analysis

GPU/MPU index and Bond return risk premia

Data summary I

• Monthly TB yields with maturities 1Y, 2Y, 3Y, 5Y and 10Y years from the federal reserve board ranging from January 1990 until June 2014, from which we bootstrap the zero-coupon yield curve treating the treasury yields as par yields.

• Our measure for observed volatility is realized volatility aggregated on a monthly level from business day data.

• Proxy for fiscal and monetary policy uncertainty based on categorical components of EPU index by Baker et al. (2012).

Government Policy Uncertainty (GPU):
① News based component (on fiscal policy uncertainty and government spending)
② Federal state/local budget disagreement
③ Tax code expiration

Monetary Policy Uncertainty (MPU):
① News based component on monetary policy uncertainty
② CPI disagreement
• Two macro factors: industrial production (IP) and Consumer price index (CPI).

• VIX index as a further measure for overall uncertainty

• Control variable for economic activity: Chicago Fed National Activity Index (CFNAI)

• Control variable for bond volatility: Treasury bond implied volatility (TIV) based on weighted average of 1 month options on treasury bonds with maturity 2, 5, 10 and 30 years

• Standard errors are based on Newey-West (HAC) estimators with three lags.
• Increase in government policy uncertainty leads to decline of nominal yields (opposite effect for MPU).
• Reduction is significant along entire term structure for GPU & MPU.
• Average $R_{adj}^2 = 0.24$ (simple) and $R_{adj}^2 = 0.52$ (with controls).
• Impact of GPU remains negative and significant for any $\tau$, also after including controls (Consistent with $H1$).
• MPU becomes insignificant.
• Average $R^2_{adj}^{GPU} = 0.17$ and $R^2_{adj}^{MPU} = -0.002$ (both simple). Very low predictive power of MPU.
• Increase in government policy uncertainty leads to an increase in yield volatility (opposite effect for MPU).
• Estimated impact of GPU peaks at 2 year maturity.
• Average $R_{adj}^2 = 0.28$ (simple) and $R_{adj}^2 = 0.56$ (with controls).
• Individual impact of GPU remains positive, hump-shaped and significant, also after including controls. (Consistent with H2 & H3.)
• MPU insignificant for any maturity.
• Average $R_{adj}^{2,\text{GPU}} = 0.26$ and $R_{adj}^{2,\text{MPU}} = 0.024$ (both simple). Very low predictive power of MPU.
**H4: Bond excess risk premia**

\[ RP(t, \tau) := \frac{1}{dt} \mathbb{E}_t \left[ \frac{dB(t, \tau)}{B(t, \tau)} - R_t dt \right] \]

\[ = \lambda_t^{N,g} \left[ b_A(\tau) \rho^{AY} \sigma_A + b_g(\tau) \rho^{gY} \sigma_g \right] \sqrt{g_t} \]

\[ + \lambda_t^{N,m} b_m(\tau) \rho^{Mm} \sigma_m \sqrt{m_t} \]

where the real market price of fiscal and monetary uncertainty are given by

\[ \lambda_t^{N,g} = \frac{\eta_2 - \eta_1}{\eta_2 - 1} \sigma_Y \sqrt{g_t}, \quad \lambda_t^{N,m} = \frac{\sigma_M}{\eta_2 - 1} \sqrt{m_t}. \]

**Model predictions:**

- Time-varying contribution to term premium of both \( g_t \) and \( m_t \)
- Excess return driven by real and monetary policy uncertainty.
• Positive, significant predictive power of GPU, also after including controls.
• Impact of MPU insignificant for any $\tau$, yet becomes significant after adding controls.
• Average $R^2_{adj} = 0.16$ (simple) and $R^2_{adj} = 0.66$ (with controls).
• Individual impact of GPU and MPU remains positive, increasing and significant (Consistent with H4).
• GPU comes insignificant once controls are added
• Average $R_{adj}^{2,\text{GPU}} = 0.08$ and $R_{adj}^{2,\text{MPU}} = 0.08$ (both simple).
  Predictability very comparable of GPU & MPU.
• Derivation of equilibrium model of the nominal term structure of interest rates and corresponding volatility curve using perturbation methods.

• Time-varying long run growth path (GPU) and link between real and nominal side is crucial to
  • replicate hump-shape term structure of bond yield volatility and
  • impact of GPU on bond risk premia.

• Empirical analysis confirm most model predictions:
  1. Higher GPU leads to lower yields (flight-to-quality).
  2. Higher GPU raises level of bond yield volatility and its contribution is hump-shaped.
  3. Both fiscal and monetary policy uncertainty are important predictor of bond risk premia. However, statistical significance of GPU vanishes when controls are added.
Thank You for Your Attention!
Appendix
Optimal Controls: Explicit solutions in the nonperturbed case

First order conditions for optimal consumption and real money holdings are given by

\[ C_t^* = \frac{K_t \left( K_t^Q e^{g(X_t)} \right)^{-\gamma}}{\beta Q} \left( \frac{\beta Q \left( K_t^Q e^{g(X_t)} \right)^{\gamma}}{K_t} R \right)^{\frac{\gamma}{\gamma - 1}} \]

\[ R := \left( \left( \frac{(\gamma - 1)\beta \frac{1}{1-\gamma} Q^{\frac{1}{1-\gamma}} K_t^{\frac{1-\gamma Q}{\gamma - 1}} e^{\frac{\gamma g(X_t)}{1-\gamma}}}{{\xi}} \right)^{\frac{1-\gamma}{\gamma \xi + \gamma - 1}} \right)^{-\xi} \]

\[ M_t^{d*} = \left( (1 - \gamma)\beta \frac{1}{1-\gamma} Q^{\frac{1}{1-\gamma}} K_t^{\frac{1-\gamma Q}{\gamma - 1}} e^{\frac{\gamma g(X_t)}{1-\gamma}}}{{\xi}} \right)^{\frac{1-\gamma}{\gamma \xi + \gamma - 1}} \]
Remarks:

- Estimate their model via quasi-maximum likelihood three moment conditions on yields, inflation and money supply (M2).
- Error is 13.21% (only volatility term structure).
• Large negative initial effect of GPU shock on 3M yields, indicates that monetary policy decisions are affected by fiscal (real) shocks.
• Short-rate shock has no impact on GPU.
Proposition (Equilibrium Nominal Term Structure of Interest Rates)

Under time-separable CRRA utility, the nominal discount bond $B(t, \tau)$ with maturity $\tau$ is given by

$$B(t, \tau) = \exp \left\{ -b_0(\tau) - b_A(\tau)A_t - b_g(\tau)g_t - b_m(\tau)m_t \right\}$$

where

$$b_A(\tau) = C_A \frac{1 - e^{-\kappa_A \tau}}{\kappa_A} ,$$

$$-b'_g(\tau) = Z_0g(\tau) + Z_1g(\tau)b_g(\tau) + Z_2 b_g^2(\tau) ,$$

$$b_m(\tau) = \frac{-Z_{1m} + H_m \cot \left( \frac{1}{2} \left( -H_m \tau - \tan \left( \frac{2\sqrt{Z_{0m} Z_{2m}}}{H_m} \right) \right) \right)}{2Z_{2m}} ,$$

$$b_0(\tau) = \int_0^\tau C_0(u) \, du$$

with $H_m = 4Z_{0m} Z_{2m} - Z_{1m}^2$, and the constant parameters $Z_{0m}, Z_{2i}, i \in \{g, m\}$ and $Z_{0g}(\tau), Z_{1g}(\tau), C_0(\tau)$ are time-to-maturity functions that only depend on the structural model parameters of the economy.
### Bond Yield Regressions I

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<td>R&lt;sub&gt;adj&lt;/sub&gt;</td>
<td>0.026</td>
<td>0.024</td>
<td>0.026</td>
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<td>0.033</td>
<td>0.035</td>
<td>0.032</td>
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<tr>
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<td>-1.615</td>
<td>-1.621</td>
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<td>t&lt;sub&gt;EPU&lt;/sub&gt;</td>
<td>(-12.18)</td>
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<td>(-14.43)</td>
<td>(-15.78)</td>
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<tr>
<td>VIX</td>
<td>-0.084</td>
<td>-0.08</td>
<td>-0.09</td>
<td>-0.12</td>
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<td>-0.146</td>
<td>-0.113</td>
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<tr>
<td>t&lt;sub&gt;VIX&lt;/sub&gt;</td>
<td>(-0.500)</td>
<td>(-0.495)</td>
<td>(-0.554)</td>
<td>(-0.803)</td>
<td>(-0.982)</td>
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<td>(-0.890)</td>
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</tr>
<tr>
<td>R&lt;sub&gt;adj&lt;/sub&gt;</td>
<td>0.462</td>
<td>0.471</td>
<td>0.492</td>
<td>0.519</td>
<td>0.533</td>
<td>0.517</td>
<td>0.478</td>
<td>0.431</td>
</tr>
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</table>

**Implications:**

- Increase in economic policy uncertainty leads to a decline of nominal yields.
- Reduction is significant along entire term structure.
- Statistical significance of VIX vanishes when EPU index is included into the regression equation.
Intermediary conclusion;

- Statistical significance of EPU index remains high.
## Bond Yield Regressions II: Term Structure of Bond Yield Volatility

<table>
<thead>
<tr>
<th></th>
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<th>6M</th>
<th>1Y</th>
<th>2Y</th>
<th>3Y</th>
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<th>7Y</th>
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<tbody>
<tr>
<td>IP</td>
<td>0.261</td>
<td>0.273</td>
<td>0.240</td>
<td>0.200</td>
<td>0.171</td>
<td>0.116</td>
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<tr>
<td>$t_{EPU}$</td>
<td>(8.62)</td>
<td>(9.15)</td>
<td>(9.20)</td>
<td>(9.47)</td>
<td>(10.30)</td>
<td>(10.05)</td>
<td>(5.72)</td>
<td>(1.22)</td>
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<tr>
<td>VIX</td>
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<td>-0.157</td>
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<td>-0.079</td>
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<td>$t_{VIX}$</td>
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<td>(-3.36)</td>
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<td>IP</td>
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<td>-0.054</td>
<td>-0.033</td>
<td>-0.020</td>
<td>-0.007</td>
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<td>0.023</td>
<td>0.039</td>
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<td>(-0.37)</td>
<td>(1.35)</td>
<td>(2.25)</td>
<td>(3.71)</td>
</tr>
<tr>
<td>$R^2_{adj}$</td>
<td>0.360</td>
<td>0.386</td>
<td>0.387</td>
<td>0.376</td>
<td>0.411</td>
<td>0.47</td>
<td>0.364</td>
<td>0.308</td>
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<table>
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<tbody>
<tr>
<td>Infl.</td>
<td>0.270</td>
<td>0.281</td>
<td>0.248</td>
<td>0.207</td>
<td>0.176</td>
<td>0.117</td>
<td>0.064</td>
<td>0.014</td>
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<td>$t_{EPU}$</td>
<td>(9.45)</td>
<td>(9.97)</td>
<td>(10.22)</td>
<td>(10.59)</td>
<td>(11.57)</td>
<td>(10.66)</td>
<td>(5.64)</td>
<td>(1.04)</td>
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<tr>
<td>VIX</td>
<td>-0.113</td>
<td>-0.118</td>
<td>-0.104</td>
<td>-0.102</td>
<td>-0.097</td>
<td>-0.092</td>
<td>-0.089</td>
<td>-0.065</td>
</tr>
<tr>
<td>$t_{VIX}$</td>
<td>(-2.31)</td>
<td>(-2.41)</td>
<td>(-2.49)</td>
<td>(-2.95)</td>
<td>(-3.57)</td>
<td>(-5.74)</td>
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</tr>
<tr>
<td>CPI</td>
<td>0.059</td>
<td>0.065</td>
<td>0.060</td>
<td>0.047</td>
<td>0.035</td>
<td>0.015</td>
<td>0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>$t_{CPI}$</td>
<td>(1.28)</td>
<td>(1.48)</td>
<td>(1.61)</td>
<td>(1.59)</td>
<td>(1.56)</td>
<td>(0.93)</td>
<td>(0.20)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>$R^2_{adj}$</td>
<td>0.352</td>
<td>0.377</td>
<td>0.394</td>
<td>0.382</td>
<td>0.418</td>
<td>0.469</td>
<td>0.347</td>
<td>0.208</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>3M</th>
<th>6M</th>
<th>1Y</th>
<th>2Y</th>
<th>3Y</th>
<th>5Y</th>
<th>7Y</th>
<th>10Y</th>
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<tr>
<td>Full</td>
<td>0.256</td>
<td>0.270</td>
<td>0.240</td>
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<td>0.175</td>
<td>0.117</td>
<td>0.065</td>
<td>0.015</td>
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<tr>
<td>$t_{EPU}$</td>
<td>(9.14)</td>
<td>(9.80)</td>
<td>(9.97)</td>
<td>(10.60)</td>
<td>(11.63)</td>
<td>(10.49)</td>
<td>(5.54)</td>
<td>(1.09)</td>
</tr>
<tr>
<td>VIX</td>
<td>-0.137</td>
<td>-0.141</td>
<td>-0.120</td>
<td>-0.114</td>
<td>-0.103</td>
<td>-0.087</td>
<td>-0.080</td>
<td>-0.051</td>
</tr>
<tr>
<td>$t_{VIX}$</td>
<td>(-3.03)</td>
<td>(-3.15)</td>
<td>(-3.06)</td>
<td>(-3.46)</td>
<td>(-3.93)</td>
<td>(-5.15)</td>
<td>(-5.35)</td>
<td>(-4.12)</td>
</tr>
<tr>
<td>IP</td>
<td>-0.090</td>
<td>-0.091</td>
<td>-0.063</td>
<td>-0.039</td>
<td>-0.019</td>
<td>0.012</td>
<td>0.026</td>
<td>0.045</td>
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<tr>
<td>$t_{IP}$</td>
<td>(-2.34)</td>
<td>(-2.39)</td>
<td>(-1.87)</td>
<td>(-1.50)</td>
<td>(-0.91)</td>
<td>(0.91)</td>
<td>(2.01)</td>
<td>(3.63)</td>
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<tr>
<td>CPI</td>
<td>0.098</td>
<td>0.105</td>
<td>0.087</td>
<td>0.062</td>
<td>0.042</td>
<td>0.011</td>
<td>-0.007</td>
<td>-0.017</td>
</tr>
<tr>
<td>$t_{CPI}$</td>
<td>(2.19)</td>
<td>(2.41)</td>
<td>(2.27)</td>
<td>(2.01)</td>
<td>(1.71)</td>
<td>(0.59)</td>
<td>(-0.41)</td>
<td>(-1.02)</td>
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<tr>
<td>$R^2_{adj}$</td>
<td>0.390</td>
<td>0.422</td>
<td>0.427</td>
<td>0.390</td>
<td>0.422</td>
<td>0.468</td>
<td>0.364</td>
<td>0.310</td>
</tr>
</tbody>
</table>
Some remarks:

- EPU index remains significant along entire term structure (except $\tau = 10$) $\rightarrow$ In line with H2
- After adding further control variables, magnitude of EPU index remains roughly the same.
- Point estimates of EPU index indicate hump-shape contribution. (highest at 6M maturity) $\rightarrow$ In line with H3.
- IP and CPI are only significant for some selected tenures $\tau$.
- Adding macro variables does not increase the $R_{adj}^2$ significantly.
Decomposing the EPU index: Yield Regressions with macro variables

<table>
<thead>
<tr>
<th>n</th>
<th>3M</th>
<th>6M</th>
<th>1Y</th>
<th>2Y</th>
<th>3Y</th>
<th>5Y</th>
<th>7Y</th>
<th>10Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPU$^g$</td>
<td>-1.130</td>
<td>-1.167</td>
<td>-1.191</td>
<td>-1.253</td>
<td>-1.250</td>
<td>-1.203</td>
<td>-1.118</td>
<td>-0.995</td>
</tr>
<tr>
<td>t$_{EPU^g}$</td>
<td>(-7.89)</td>
<td>(-7.99)</td>
<td>(-8.19)</td>
<td>(-8.91)</td>
<td>(-9.35)</td>
<td>(-9.62)</td>
<td>(-9.13)</td>
<td>(-8.42)</td>
</tr>
<tr>
<td>EPU$^r$</td>
<td>-0.468</td>
<td>-0.474</td>
<td>-0.473</td>
<td>-0.410</td>
<td>-0.344</td>
<td>-0.184</td>
<td>-0.111</td>
<td>-0.021</td>
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<tr>
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<td>(-3.10)</td>
<td>(-3.09)</td>
<td>(-3.10)</td>
<td>(-2.65)</td>
<td>(-2.24)</td>
<td>(-1.21)</td>
<td>(-0.73)</td>
<td>(-0.14)</td>
</tr>
<tr>
<td>VIX</td>
<td>0.372</td>
<td>0.375</td>
<td>0.351</td>
<td>0.271</td>
<td>0.203</td>
<td>0.085</td>
<td>0.057</td>
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<tr>
<td>t$_{VIX}$</td>
<td>(2.30)</td>
<td>(2.37)</td>
<td>(2.25)</td>
<td>(1.70)</td>
<td>(1.30)</td>
<td>(0.58)</td>
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<td>(-0.10)</td>
</tr>
<tr>
<td>IP</td>
<td>0.338</td>
<td>0.331</td>
<td>0.328</td>
<td>0.290</td>
<td>0.231</td>
<td>0.156</td>
<td>0.119</td>
<td>0.074</td>
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<tr>
<td>t$_{IP}$</td>
<td>(1.83)</td>
<td>(1.77)</td>
<td>(1.76)</td>
<td>(1.54)</td>
<td>(1.26)</td>
<td>(0.91)</td>
<td>(0.71)</td>
<td>(0.48)</td>
</tr>
<tr>
<td>CPI</td>
<td>0.864</td>
<td>0.893</td>
<td>0.851</td>
<td>0.801</td>
<td>0.754</td>
<td>0.687</td>
<td>0.643</td>
<td>0.604</td>
</tr>
<tr>
<td>t$_{CPI}$</td>
<td>(3.98)</td>
<td>(4.17)</td>
<td>(4.02)</td>
<td>(3.67)</td>
<td>(3.50)</td>
<td>(3.35)</td>
<td>(3.23)</td>
<td>(3.27)</td>
</tr>
<tr>
<td>$R_{adj}^2$</td>
<td>0.597</td>
<td>0.607</td>
<td>0.615</td>
<td>0.614</td>
<td>0.607</td>
<td>0.579</td>
<td>0.547</td>
<td>0.514</td>
</tr>
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</table>

Observations:

• Indicates that only uncertainty with respect to government policy remains significant (for all $\tau$).

• Uncertainty not related to government policy becomes insignificant (long end).

• Explanatory power remains high ($R_{adj}^2$’s are almost identical).
Decomposing the EPU index: Yield Volatility Regressions including Macro Variables

<table>
<thead>
<tr>
<th>$\tau$</th>
<th>3M</th>
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<th>3Y</th>
<th>5Y</th>
<th>7Y</th>
<th>10Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU</td>
<td>0.310</td>
<td>0.332</td>
<td>0.296</td>
<td>0.239</td>
<td>0.197</td>
<td>0.118</td>
<td>0.059</td>
<td>0.006</td>
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<tr>
<td>$t_{GPU}$</td>
<td>(7.35)</td>
<td>(7.50)</td>
<td>(7.54)</td>
<td>(7.41)</td>
<td>(7.70)</td>
<td>(7.13)</td>
<td>(4.14)</td>
<td>(0.42)</td>
</tr>
<tr>
<td>MPU</td>
<td>-0.098</td>
<td>-0.084</td>
<td>-0.072</td>
<td>-0.052</td>
<td>-0.034</td>
<td>-0.002</td>
<td>0.009</td>
<td>0.016</td>
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<tr>
<td>$t_{MPU}$</td>
<td>(-2.00)</td>
<td>(-1.73)</td>
<td>(-1.69)</td>
<td>(-1.48)</td>
<td>(-1.21)</td>
<td>(-1.3)</td>
<td>(0.58)</td>
<td>(1.06)</td>
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<tr>
<td>VIX</td>
<td>-0.069</td>
<td>-0.080</td>
<td>-0.067</td>
<td>-0.072</td>
<td>-0.073</td>
<td>-0.077</td>
<td>-0.079</td>
<td>-0.056</td>
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<tr>
<td>$t_{VIX}$</td>
<td>(-1.42)</td>
<td>(-1.66)</td>
<td>(-1.56)</td>
<td>(-2.01)</td>
<td>(-2.57)</td>
<td>(-4.26)</td>
<td>(-5.25)</td>
<td>(-4.38)</td>
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<td>-0.091</td>
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<td>-0.025</td>
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<td>0.025</td>
<td>0.048</td>
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<td>(-2.79)</td>
<td>(-2.14)</td>
<td>(-1.97)</td>
<td>(-1.36)</td>
<td>(0.70)</td>
<td>(1.93)</td>
<td>(3.79)</td>
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<tr>
<td>CPI</td>
<td>0.102</td>
<td>0.107</td>
<td>0.088</td>
<td>0.072</td>
<td>0.051</td>
<td>0.014</td>
<td>-0.007</td>
<td>-0.021</td>
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<tr>
<td>$t_{CPI}$</td>
<td>(2.44)</td>
<td>(2.62)</td>
<td>(2.46)</td>
<td>(2.45)</td>
<td>(2.13)</td>
<td>(0.75)</td>
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<td>(-1.24)</td>
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<tr>
<td>$R^2_{adj}$</td>
<td>0.414</td>
<td>0.438</td>
<td>0.439</td>
<td>0.416</td>
<td>0.448</td>
<td>0.470</td>
<td>0.361</td>
<td>0.301</td>
</tr>
</tbody>
</table>

Remarks:

- Hump-shape structure in point estimates of GPU index remains statistically significant.
- MPU and IP essentially irrelevant.
- CPI only statistically significant at the short to medium length of $\tau$.
- Also, suggests that only government policy uncertainty is driving movements in the term structure of bond volatility.
References I


References II


References III


